ENERGY BANDS AND GAPS IN SEMICONDUCTOR

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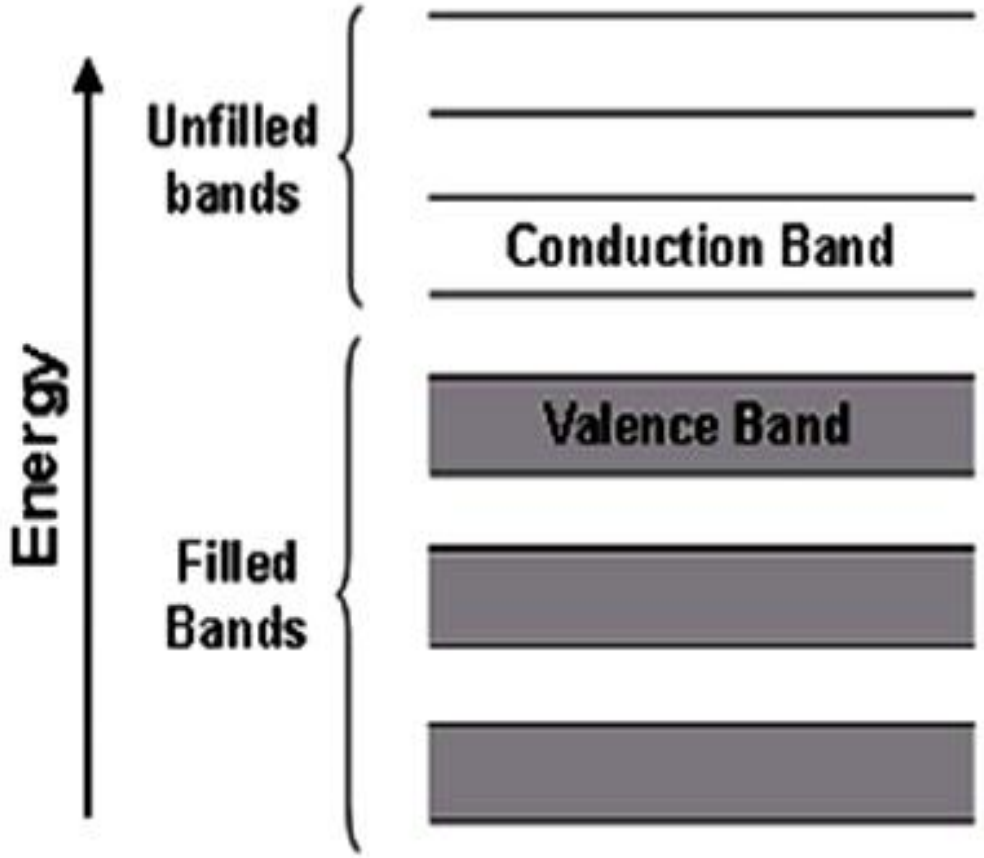
INTRODUCTION

- Si= 14 electrons
- 4 valence electrons
- Electrons present in the outermost orbit are called valence e- and their behavior decide electrical characteristics of a materials.
- When the atoms are brought to closer, the interaction b/w increases and they now form a electronic system.

ENERGY BANDS THEORY

- There Important energy bands are,
- Valence Band
- Conduction Band
- Forbidden Band



Valence Band

- Band of energy level which are closer to nucleolus.
- An e- in valence band, expenses strong force of attraction from nucleolus.
- And it can’t move freely when external electric field is applied.
- It is called bounded electron.

Conduction Band

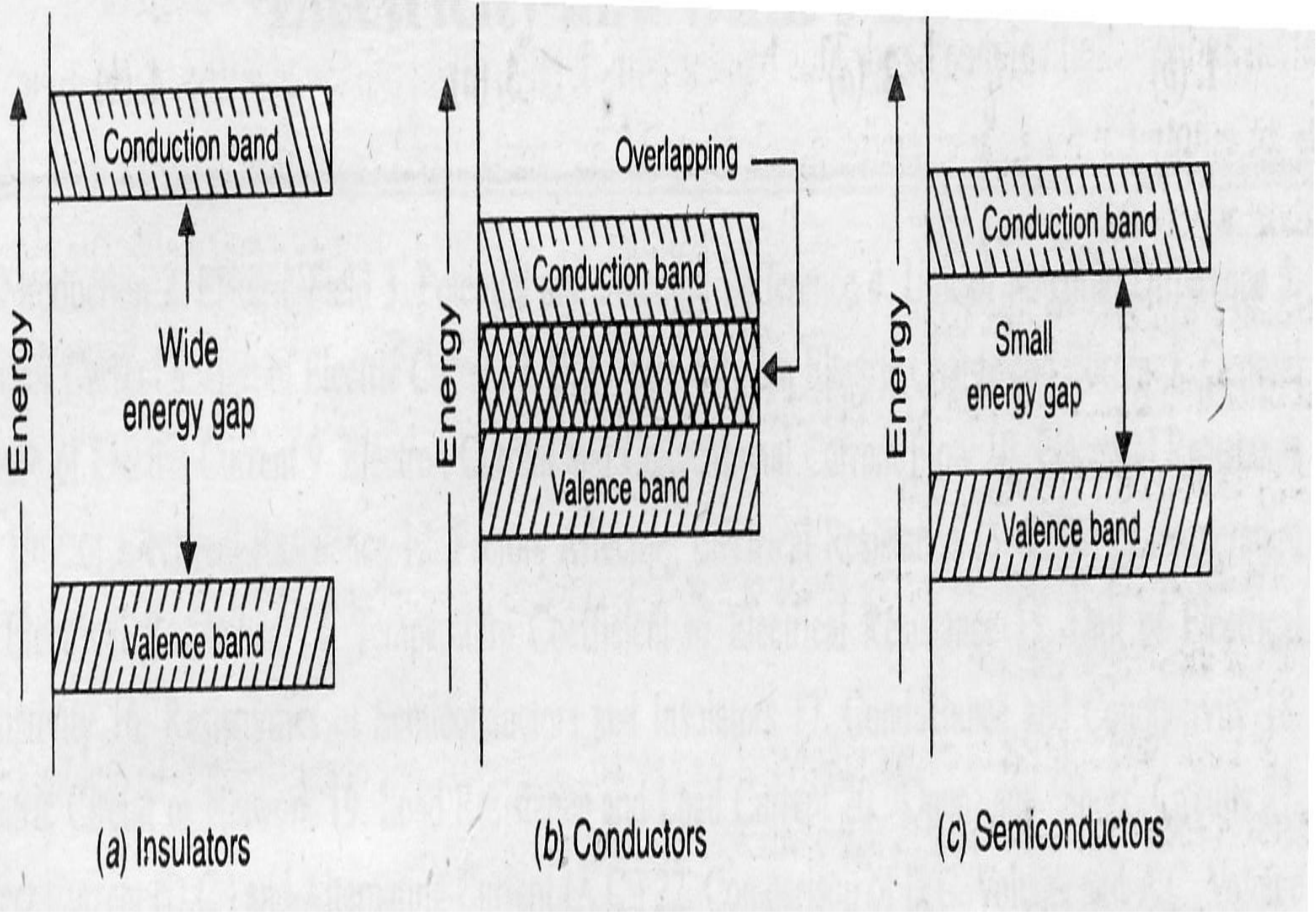
- Bond of energy levels which are far away from the nucleolus.
- The conduction band is the band of orbitals that are high in energy and are generally empty.
- An e- in Conduction band has weak influence of nucleolus and hence it can move free under the effect of applied electric field and thus it produces current, it is called free electrons

Forbidden Band / Energy Gap

- In solid-state physics, an **energy gap** or **band gap**, is an energy range in a solid where no electron states can exist.
- It generally refers to the energy difference (in electron volts) between the top of the valence band and the bottom of the conduction band in insulators and semiconductors.

Types of Materials

- Materials can be divided into 3 types based on the values of energy gap
- Insulator
- Conductor
- Semi Conductor


Energy
Conduction band
Wide
energy gap
Valence band
(a) Insulators
Energy
Overlapping
Conduction band
Valence band
(b) Conductors
Energy
Conduction band
Small
energy gap
Valence band
(c) Semiconductors

INSULATORS

- It is a material with large energy gap
  - Eg= several ev
  - ev= $1.6*10^{-19}$ joules
- Due to large energy gap an e^- from valence band can't move into conduction band remains complete fill.
- Conduction band completly empty.
- Ex: glass, Diamond, Silicon di oxide

- Energy gap of diamond is ~6ev.

CONDUCTORS

- It is a material having zero energy gap. The materials in which conduction and valence bands.
- Valence electrons can move valence to conduction band without requiring thermal energy.
- The overlapping indicates a large number of electrons available for conduction.
- Hence the application of a small amount of voltage results a large amount of current.
- Ex: All metals.
- Best conducting materials are
  - Silver is best, cupper is second best

SEMICONDCUTOR

- The materials, in which the conduction and valence bands are separeated by a small energy gap (1eV) are called semi-conductors.
- Silicon and germanium are the commonly used semiconductors.
- A small energy gap means that a small amount of energy is required to free the electrons by moving them from the valence band in to the conduction band.
- The semiconductors behave like insulators at 0K, because no electrons are available in the conduction band.
- If the temperature is further increased, more valence elctrons will acquire energy to jump into the conduction band.

SEMICONDCUTOR

- If a valence receives sufficient thermal energy, it can move into conduction band leaving a vacancy in valence band, which is called hole and therefore, if one e^- is sufficiently thermally energized it creates a pair of free e^- and hole, this process is called carrier generation
- Carrier generation can happen due to
  - Thermal excitation
  - Photo excitation
  - Electrical excitation
  - Impact ionization

Internal Currents

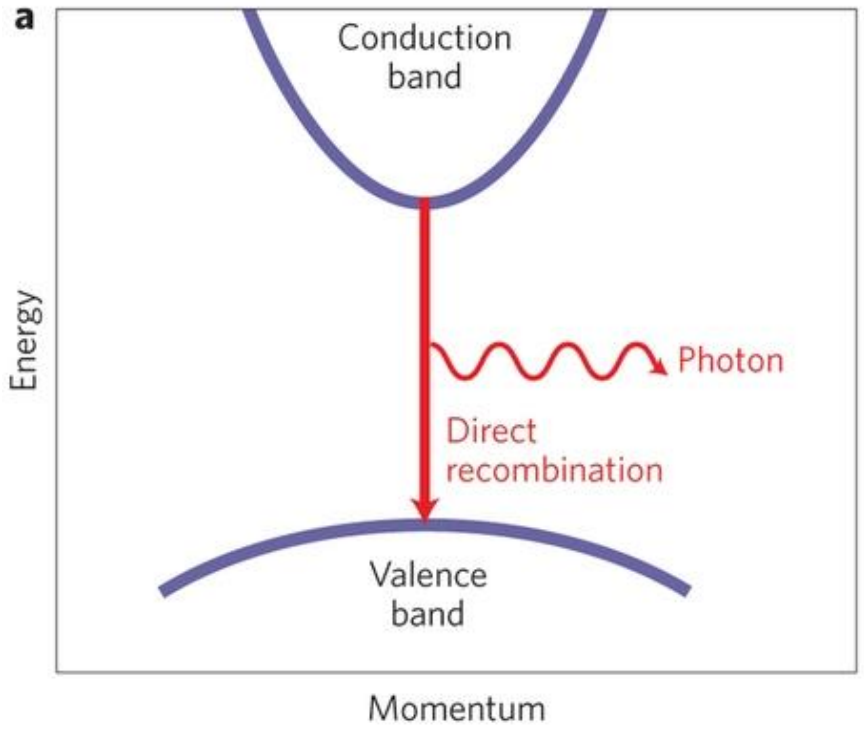
- When external electric field is applied free electron travels with in conduction band producing electron current.
- Where as hole travels in valence, producing hole current.
- The total current will be sum of free & hole current.
- $I_{total} = I_{free\ e^-} + I_{hole}$
- As temp increase free e^- & holes will increase and conductivity increases.

Direct & Indirect band gap SC

- The process of free e- returning from conduction band to valence band which causes disappearance of a free e- , hole pair is called carrier recombination.
- SC are divided into 2 types based upon the method of recombination.
  - Direct band gap SC
  - Indirect band gap SC

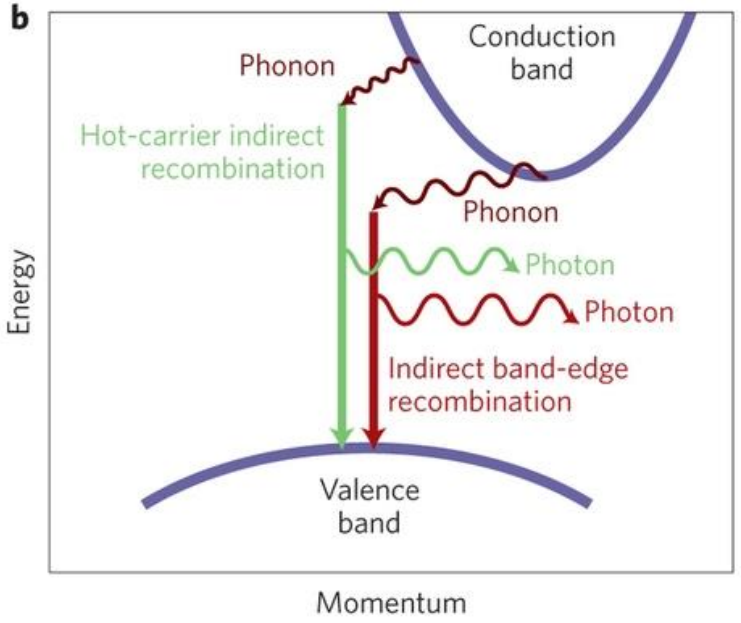
Direct band gap SC

- For these SC , Conduction band minima and valence band maxima occurs at same value of momentum.
- An e- from CB directly return to VB without changing It's momentum. And releases energy in the form of light (photon hv).



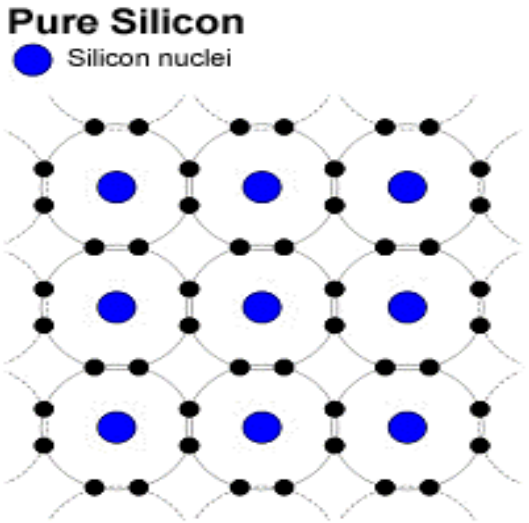
Indirect band gap SC

- CB minima and VB maxima occurs at different value of momentum.
- When e- from CB returns VB after changing its momentum is called indirect band gap sc.
- E- changes its momentum by releasing phonon which is a heat particle.
- Ex: Si, Ge



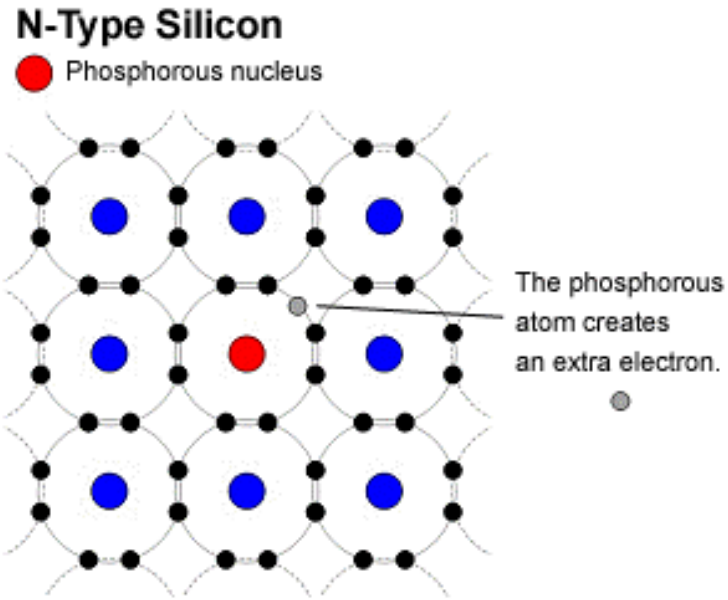
Intrinsic SC

- IV group is carbon, Si, Ge, Tin, Lead.
- In it sc crystal each atom forms four covalent bonds to become stable.
- At 0^0 , all valence e- participate in covalent band formation. Conduction not possible.
- if temp is increases, greater no of free e- hole pair will be created. Causes conduction



N type SC

- V^{th} group Phospurs, Arsenic, Antimon.
- P forms 4 covalent bonds with Si and donate 5^{th} electron to crystal. It is called free e-.
- According to law of Nutrality $n_n=p_n+n_D$
- Mass action law $n_{n*}p_{n=}n_i^2$
- Majority is e-
  minority is holes



P type SC

- 3rd group B, Al, Ga.
- B forms 3 covalent bonds with Si and forms 4th bond with hole formation.
- According to law of Nutrality and Mass action law
- Majority is holes
  minority is e^-